ORIGINAL ARTICLE

Investigation of Infant Brain with or without Hydrocephalous in Our Environment Using Anterior Transfontanelle Ultrasound Scan

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ABSTRACT

Aim: A prospective study aimed to suggest easy and simple reproducible ventricular site that will be basic measurement plane and normal dimension determined, correlated to sizes of infants for comparative evaluation of hydrocephalous infants and should be reproducible in follow-up. **Materials and Methods:** A prospective study done in University of Benin Teaching Hospital Benin, Nigeria. This study used 50 consecutive infants with Ultrasound scan (US) diagnosis of hydrocephalus and a control group of 50 US normal from 1st January 2007 to 30th June 2008. The infants were scan through the mid-patent anterior fontanelle in sagittal, and transverse planes with minor angulations to properly outline the ventricles and the position of measurement determined at the foramen of Monro of lateral ventricles and the diameter measured. The infants' weight, crown–heel length, and head circumference were measured and body mass index (BMI) calculated and correlated to lateral ventricular measurement. Data analysis was conducted using the Statistical Package for Social Sciences (SPSS Inc, USA), Version 11.0. **Results:** There was no statistically sex and age-related difference. There is statistically comparative high mean weight and height and lower BMI in hydrocephalic infants as against the control group ($P < 0.001$). The mean head circumference for hydrocephalus was 45.6 (± 10.5 standard deviation [SD]), whereas the control group was 35.9 (± 2.7 SD) with $P < 0.001$. The mean diameter of the anterior horn of left and right lateral ventricles at the level of foramen of Monro in hydrocephalic subjects is 18.4 mm ± 14.3 mm and 20.1 mm ± 16.8 mm with median diameter of 14.1 mm and 15.2 mm, respectively, whereas control group is 2.5 mm ± 0.6 mm and 2.5 mm ± 0.7 mm with median diameter of 2.5 mm and 2.4 mm, respectively. **Conclusion:** Transfontanelle US was found highly useful in investigation of hydrocephalous in infant.

KEYWORDS: Anterior fontanelle, brain, hydrocephalus, ultrasound, ventricle

production caused by choroid plexus papilloma.[1] Most times, the diagnosis of hydrocephalus in infants is made clinically when there is abnormal increase in head circumference. Other clinical features include vomiting, sleepiness, irritability, downward deviation of the eyes "sun-setting," and seizures. Late presentation and late clinical diagnosis of hydrocephalus may be followed by poor prognosis which may appear as mental retardation, cerebral palsy, and even death of the patient.[2] Early diagnosis can be made with transfontanelle Ultrasound scan (US), but the drawback in our environment is absence of comparative measurement value of normal ventricular size range. Since the brain is a very delicate organ, and histologically, has no regenerative capability; it is necessary to employ a non-invasive and non-ionizing radiation procedure to accomplish an early diagnosis. In our environment, US is readily available, cheap, easily employed, and carried out as a bed side procedure with no risk of ionizing radiation.[3] The anterior fontanelle of the calvarium serves as acoustic window for imaging of the infant's brain.[1] A limited access is also possible through the posterior fontanelle and widened sutures. Also direct imaging with US can be done through the membranous temporal bone of the skull.[2]

US exposure causing temperature rise of greater than 4 degree centigrade is known to physically generate increased heating of the tissue and may lead to tissue cell cavitations when probe is placed at one position persistently for over 5 min. However, long-term follow-up of this effect has not established any link to any known abnormalities in the literature at the diagnostic

INTRODUCTION

Hydrocephalus can be defined as the excessive accumulation of cerebrospinal fluid (CSF) resulting in dilatation of cerebrospinal compartment in the cranium and also may be congenital or acquired in origin. Hydrocephalus may be due to obstruction to normal flow, or faulty absorption and occasionally excessive CSF

frequencies in which US is used in medicine.[4]

Many researchers have used different transducer frequency in infant anterior transfontanelle brain scan ranging from 3.5 MHz to 10 MHz, depending on the level of tissue penetration required. For superficial structure range, above 5 MHz may be required.[2,4]

The other radiological modalities used for the evaluation of the infant's brain are available but they tend to have significant drawback in infants. They include plain radiographs of the skull, conventional tomography, and cross-sectional imaging such as computed tomography (CT) and magnetic resonance imaging (MRI). Plain radiography, conventional tomography, and CT employ ionizing radiation. Plain radiograph diagnosis is inferred based on findings of sutural diastasis, intracranial calcification, and craniofacial disproportion. These findings do not show structural ventricular defect. Although both CT and MRI give very good two-dimensional images and ability for three-dimensional reconstructions with focalization, it is costly and not readily available in our environment. Also the procedure is a little cumbersome and required sedation of infant for adequate cooperation during the procedure. The conventional tomography is almost obsolete in our practice.

The purpose of this study is to show comparative US findings in infants less than 12 months with hydrocephalus and the normal infant at the University of Benin Teaching Hospital (UBTH), Benin City Nigeria with a view of determining reproducible normal focal lateral ventricular size above which diagnosis of hydrocephalus is highly probable. This is meant to encourage early diagnosis and avoid associated complication.

MATERIALS AND METHODS

This study is a prospective study of 50 consecutive infants with clinical diagnosis of hydrocephalus and a control group of 50 infants clinically certified normal; totally, 100 infants had anterior transfontanelle ultrasound scan done in Department of Radiology UBTH, Benin City Nigeria from 1st January 2007 to 30th June 2008. Informed consent was obtained from parent of the infants and ethical consent in line with the center guidelines. Before transfontanelle scan, each baby was weighed in kilogram, the crown–heel length in centimeters measured, and the body mass index (BMI) in kg/m^2 was calculated. The baby's head circumference (occipitofrontal) in centimeters was also measured. These bio data, including age in days, sex, and reason for US and diagnosis were documented and analyzed.

Infants without patent anterior fontanelle and above the age of 12 months were excluded from the study. Then each of the infants was scanned through the patent anterior fontanelle in sagittal, and transverse or coronal plains with minor angulations to properly outline the ventricles. The subjects were placed in most comfortable position mainly supine or on the mother's laps. The equipment used was a Sonoace 1,500 (Medison Corporation, South Korea, 1998) ultrasound machine using a curvilinear real-time probe with transducer frequency of 6.5 MHz.

The sagittal anterior transfontanelle US angulations from mid-line are 15 degree and 30 degree laterally, while coronal scan angulations pass firstly anteriorly through the frontal lobes, secondly vertically through sylvian fissures, thirdly minimally posterior vertically through the 3rd ventricle, and fourthly posteriorly through the highly echogenic tentorium and cerebellum [Figures 1 and 2]. The measurements were
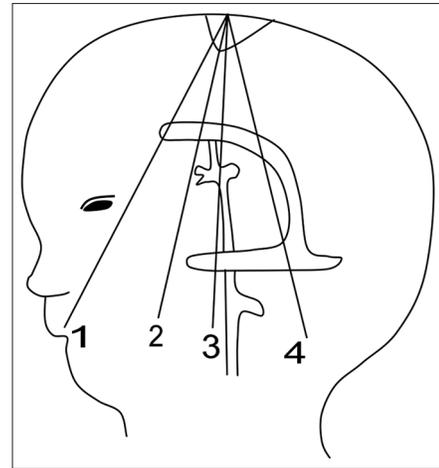

Figure 1: Sketch of infant skull showing the sites of four coronal scan sections. Key 1 = 1st coronal plane pass anterior fontanelle to show frontal lobes separated at the center by interhemispheric fissures and falx. 2 = 2nd coronal plane pass sylvian fissures behind lesser wings of sphenoid to show Anterior horns of lateral ventricles seen as slit-like spaces on either side of central midline echo connecting. 3rd through foramen monro. 3 = 3rd coronal plane, passes through the 3rd ventricle. 4 = 4th coronal plane pass the highly echogenic tentorium and cerebellum shaped like inverted V
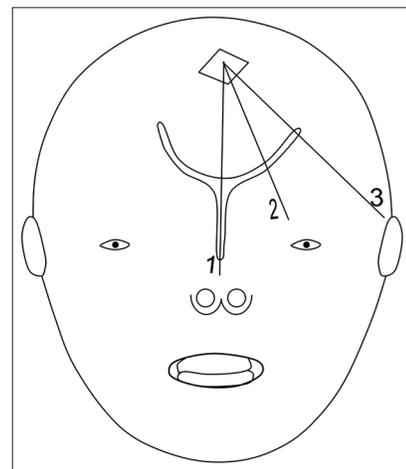

Figure 2: Sketch of infant skull showing the sites of three standard sagittal scan sections. Key 1 = 1st sagittal section: Mid-line shows sulcal details, echogenic cerebellum posteriorly, and the 4th ventricle anteriorly. 2nd parasagittal section is angled 15 degree away from mid-line. Shows full sweep of lateral ventricle containing echogenic choroid plexus and thalamus and caudate nucleus within the sweep. 3rd parasagittal section is angled 30 degree lateral to show the ventricle through the Sylvian fissure

documented on the mid-coronal image which showed the diameter of the anterior horn of the lateral ventricles at the level of foramen of Monro in both hydrocephalic and normal control group [Figures 3 and 4]. Data analysis was conducted using the Statistical Package for Social Sciences (SPSS Inc, USA), Version 11.0 and data comparison (statistical test of significance) was done with Chi-square (χ^2) test. Significance was set at a $P \leq 0.05$. Confidence interval was calculated at 95%.

RESULTS

There were equal number of males and females in the hydrocephalic group; i.e., 25 (50%), respectively, while there were more males (34, 68%) than females (16, 32%) in the control group.

The age range of the hydrocephalic group was 0-240 days with a

mean of 59.3 days (± 65.3 standard deviation (SD)), whereas in the control group, the age range was 0-270 days with a mean of 56.4 (± 64.0 SD). The age range with the highest representation was 0-60 days in both groups accounting for 33 (66.0%) and 38 (76%) in the hydrocephalic infants and control group, respectively [Figures 5 and 6]. The mean, SD and median weight, height, BMI, and head circumference of the hydrocephalic infants and the control group were shown in Tables 1 and 2. The mean head circumference for the hydrocephalic infants was 45.6 cm (± 10.5 SD), while that of the control group was 35.9 cm (± 2.7 SD).

The mean diameter of the anterior horn of the left and right lateral ventricles in the hydrocephalic infants is 18.4 mm ± 14.3 mm and 20.1 mm ± 16.8 mm with a median of 14.1 mm and 15.2 mm, respectively [Table 3]. The mean diameter of the anterior horn of the left and right lateral ventricles in the control group is 2.5 mm ± 0.6 mm and 2.5 mm ± 0.7 mm with a median of 2.5 mm and 2.4 mm, respectively. The clinical indications for requesting transfontanelle US in the study group in decreasing order were: Spina bifida (26.0%), post-meningitis (20%), suspected
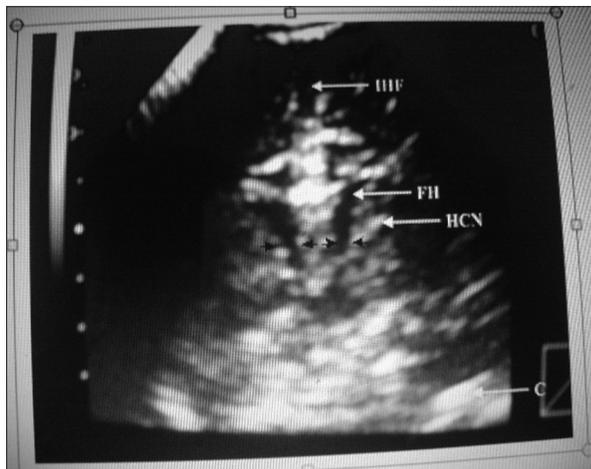

Figure 3: Sonogram of vertical coronal section through the frontal horns in a normal transfontanelle scan at the level of the foramen of Monro. FH = Frontal horn of lateral ventricle connecting 3rd ventricle through foramen of Monro. HCN = Head of caudate nucleus; IHF = Interhemispheric fissures

Figure 4: Sonogram of vertical coronal section in a child with non-communicating hydrocephalus with obstruction at the level of Aqueduct of Sylvia. Both lateral and third ventricles are markedly dilated. Note the connection between the ventricles through foramen of Monro

Table 1: Anthropometric measurements in the study groups

Anthropometric measurements	Hydrocephalic infants			Control group		
	Mean	SD	Median	Mean	SD	Median
Age (day)	59.3	65.3	32.5	56.4	65.0	30.0
Weight at presentation (kg)	5.3	2.1	5.1	4.3	1.0	4.1
Birth weight	3.3	0.7	3.1	3.2	0.5	3.1
Length at presentation (cm)	63.9	10.8	68.0	55.1	7.5	52.0
Body mass index at presentation (kg/m²)	12.5	3.2	11.5	14.1	2.1	14.0
Head circumference at presentation (cm)	45.6	10.5	44.5	35.9	2.7	36.0

SD: Standard deviation

Table 2: Comparison of anthropometric measurements in males and females of the hydrocephalic group

Anthropometric measurements	Male			Female		
	Mean	SD	Median	Mean	SD	Median
Age (day)	48.7	47.6	35.0	69.7	78.9	27.0
Weight at presentation (kg)	5.2	2.2	4.8	5.3	2.0	5.4
Length at presentation (cm)	64.3	11.8	68.4	63.6	9.9	67.8
Body mass index at presentation (kg/m²)	12.1	3.0	11.2	13.0	3.5	11.9
Head circumference at presentation (cm)	48.1	10.5	48.0	43.0	10.1	41.5

SD: Standard deviation

hydrocephalus (20%), and congenital hydrocephalus (16%). Both increasing head size and delayed developmental milestones accounted for 18% [Figure 7].

Anterior transfontanelle US evaluation of the infants showed that the pathophysiological causes of hydrocephalus are divided into communicating and non-communicating types. Communicating hydrocephalus accounted for 56%, whereas non-communicating hydrocephalus was 44% [Table 4].

The causes of hydrocephalus as shown by anterior transfontanelle US fell into two main groups: Congenital (78%) and post-meningitis or acquired (22%) [Table 5].

Table 6 shows significant association between head circumference and the BMI in the hydrocephalic infants ($P < 0.05$) while there was no significant association between BMI and the lateral ventricles ($P > 0.05$).

DISCUSSION

Anterior transfontanelle US is a form of evaluation of the intracranium.[5,6] The practice is gradually gaining prominence in our hospital, especially in investigation of infants with suspected intracranial lesions. The common use is in diagnosis of hydrocephalous. The aim of this study as outlined earlier is to determine comparative normal ventricular diameter range

Table 3: Comparison of the diameter of the anterior horn of the lateral ventricles measured at the level of foramen of monro of the hydrocephalic infants and control group

Total	Hydrocephalic infants			Control group		
	Mean (mm)	SD (mm)	Median (mm)	Mean (mm)	SD (mm)	Median (mm)
Left lateral ventricle	18.4	14.3	14.1	2.5	0.6	2.5
Right lateral ventricle	20.1	16.8	15.2	2.5	0.7	2.4

$P>0.05$

Table 4: Distribution of types of hydrocephalus and associated anomalies as seen on transfontanelle scan

Types of hydrocephalus	No. of cases	Percentage
Communicating	28	56.0
Non-communicating	22	44.0
Total	50	100.0

Table 5: Cause of hydrocephalus as diagnosed at anterior transfontanelle ultrasound scan

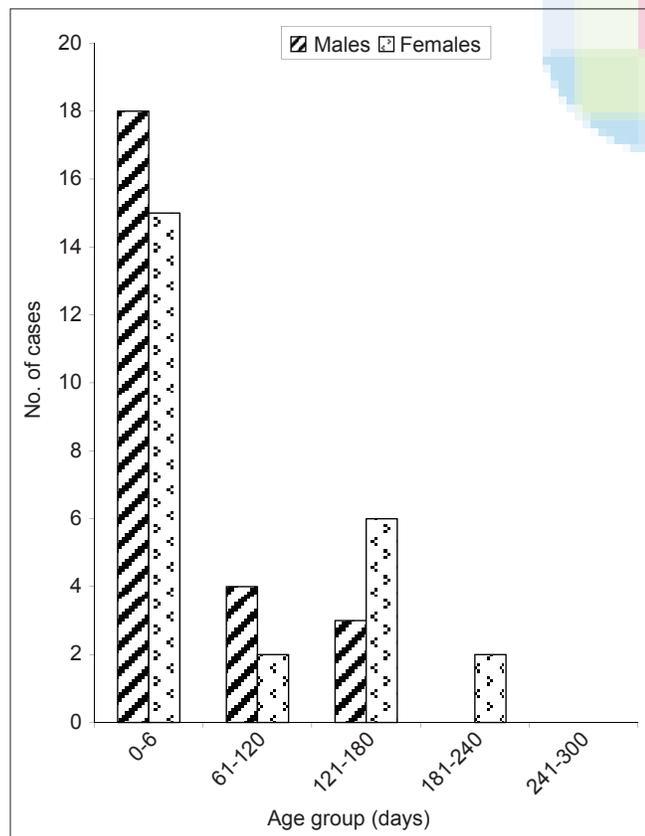| Cause	No. of cases	Percentage
Congenital hydrocephalus	39	78
Acquired hydrocephalous	11	22.0
Total	50	100.0

Figure 5: Bar chart showing age and sex distribution of hydrocephalic infants (study group)
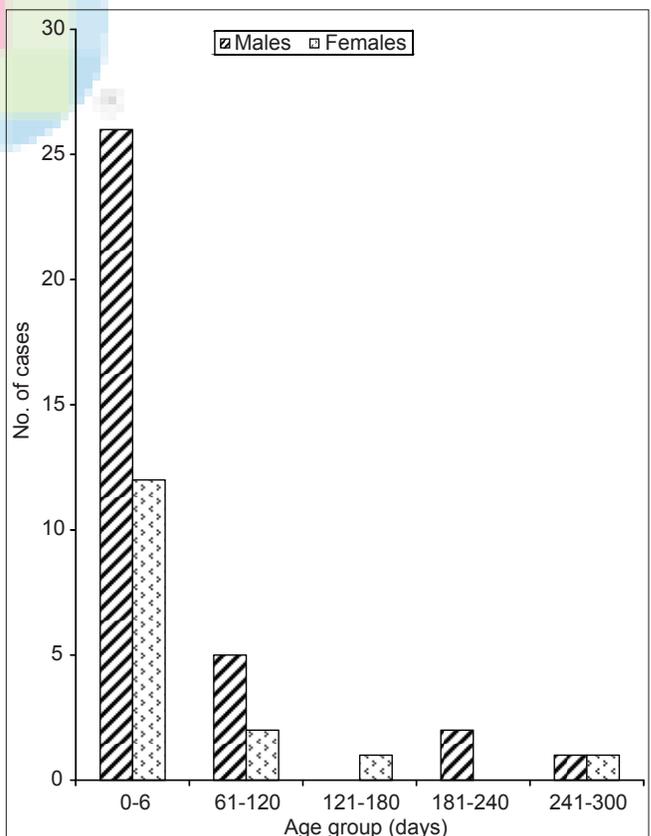

Figure 6: Bar chart showing age and sex distribution of healthy infants (control group)
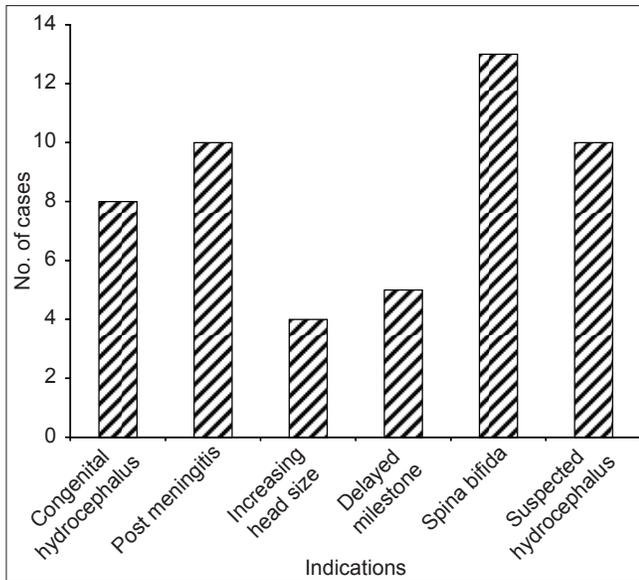
Figure 7: Bar chart showing distribution of indications for transfontanelle ultrasound scan

which will be the baseline defining disproportional ventricular dilatation. The value of US as follow-up investigation cannot be overemphasized, since no significant negative effect from the investigation on brain tissue has been detected.[4] This was the reason why this study aimed to suggest easy and simple reproducible ventricular site that will be basic measurement standard for comparative evaluation and that could also be reproducible in follow-up evaluation. The lateral ventricular diameter at the level of the foramen of Monro was taken because its' position is considered the first likely site; ventricular dilatation will occur in event of drainage obstruction and is easily reproducible. The study showed that the mean diameter of the anterior horn of the left and right lateral ventricles in the hydrocephalic infants is 18.4 mm ± 14.3 mm and 20.1 mm ± 16.8 mm with a median of 14.1 mm and 15.2 mm, respectively, whereas the mean diameter of the anterior horn of the left and right lateral ventricles in the control group is 2.5 mm ± 0.6 mm and 2.5 mm ± 0.7 mm with a median of 2.5 mm and 2.4 mm, respectively [Table 3]. A comparison of the mean diameter of the anterior horn of the left and right lateral ventricles of both hydrocephalic infants and control group showed statistically significant difference with high values in hydrocephalic patients. However, there was no significant difference between the diameters of the left and right lateral ventricle in control group with $P > 0.05$. Hence, the mean diameter of 2.5 mm ± 0.7 mm for both right and left lateral ventricle is deducted as normal. However, in the hydrocephalic infants, they showed asymmetrical enlargement of anterior horn of lateral ventricle at foramen of Monro with $P > 0.05$. This is attributed to disproportional increasing pressure in the cerebrospinal drainage pathway in the hydrocephalous compared to the normal control group which is in equilibrium.

Some work has been done by many researchers in the suitability of US intracranial evaluation. Graziani et al.,[7] conducted serial ultrasound studies of cerebral ventricular size on 40 small pre-term infants, 26 of whom were believed to be at risk of intracranial hemorrhage or hydrocephalus secondary to intracranial hemorrhage or both. Hydrocephalus was diagnosed by ultrasound study in 12 of the high-risk infants, eight of whom required a surgical shunt procedure because of progressive ventricular enlargement. They found that serial ultrasound measurements and images proved clinically useful in the initial detection of hydrocephalus and subsequent evaluation of the infant subjects. Babcock et al.,[8] compared intracranial US and pathological findings of 25 autopsied pre-mature infants and found good correlation between ultrasound and autopsy findings. Nzeh et al.,[3,9] in a study to evaluate the importance of transfontanelle ultrasonography of the infant brain, observed that 38 (38.8%) of the 98 infants had hydrocephalus from various causes, whereas 26 (25.5%) had congenital anomalies. Adeloye and Khare,[10] in an ultrasonographic study of 80 Malawian children aged below 15 months suspected to have hydrocephalus clinically, found 68 (85%) of the cases were post-infective, 14 (20.6%) were associated with lumbosacral myelomeningocele, 13 (19.1%) were post-hemorrhagic, and the rest probably congenital or idiopathic. Our study was based on structural ventricular pathway pattern and found that communicating hydrocephalus accounted for 56%, whereas non-communicating hydrocephalus was 44% [Table 4]. The causes of hydrocephalus as shown by anterior transfontanelle US fell into two main groups: Congenital (78%) and post-meningitis or acquired (22%) [Table 5]. This is not far from what the previous researchers have found. The highest occurrence of hydrocephaly in our study is at neonatal period (0-60 days) and there was no sex bias found. This can also be attributed to referral basis and tertiary hospital base of the study. Hydrocephalus is a common central nervous system disorder in children with variable incidence in different communities.[2,11] In Nigerian communities, the studies available are hospital-based surveys.[12,13] A previous study done in our center has found Transfontanelle ultrasonography a useful technique for diagnosis of lesions within the infant brain and hydrocephalus is the most frequent reason for request.[13] A lot of patients may have been lost in the community due to un-presentation in the appropriate hospital setting.[13]

We also noticed that the height and weight of the hydrocephalic infant are higher in value than the normal infant, and BMI of the hydrocephalic infants is lower than the normal control group. This is attributed to increase in cranial size due to fluid accumulation. This was confirmed clinically by the finding that the mean head circumference for the hydrocephalic infants was 45.6 cm (± 10.5 SD), while that of the control group was 35.9 cm (± 2.7 SD) [Table 2]. There was significant association between head circumference and the BMI in the hydrocephalic infants ($P < 0.05$) [Table 6].

Table 6: Test for significant association between BMI, head circumference, indication, left lateral ventricle, right lateral ventricle and findings

Test	χ^2 value	Df	P value
BMI versus head circumference	18.971	9	Significant ($P<0.05$)
BMI versus indication	24.691	15	Not significant ($P>0.05$)
BMI versus left LV	8.305	9	Not significant ($P>0.05$)
BMI versus right LV	10.862	9	Not significant ($P>0.05$)
BMI versus findings	13.831	12	Not significant ($P>0.05$)

BMI: Body mass index, LV: Lateral ventricle

CONCLUSION

This study has found the normal focal lateral ventricular dimension at the level of the foramen of Monro. This method is simple, easily reproducible, and can be used as baseline from which the diagnosis of hydrocephalus can be made and follow-up comparison undertaken. Further comparison of the study findings with many other previous researchers has confirmed versatility of US in diagnosis of intracranial lesions.

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